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DISTRIBUTION PATTERNS OF *Baetis* (EPHEMEROPTERA: BAETIDAE) AS TOLERANT TAXA IN FRESHWATER BIOLOGICAL MONITORING

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ABSTRACT

The abundance and distribution of seven *Baetis* sp. (*Baetis gombaki, Baetis idei, Baetis illiesi, Baetis laetificus, Baetis lepidus, Baetis minutus* and *Baetis mirabilis*) from Order Ephemeroptera (Family: Baetidae) in four rivers from Bukit Merah catchment area, Perak were studied. From this study, Sungai Ara was classified as the most preferred habitat and hotspot area for all the *Baetis* sp. Out of seven species, *B. illiesi* (120 individuals) was the dominant species while *B. laetificus* was the most sensitive taxa. This study indicates that abundance, distribution and composition of *Baetis* sp. in each river appeared to respond to the water quality parameters. *B. idei* showed positive correlation with water temperature (r=0.723, *P*=0.00) and Biochemical Oxygen Demand (r=0.719, *P*=0.00). *B. gombaki* was the least sensitive species as it is only correlated with water temperature (r=0.499, *P*=0.001). Sungai Kurau was considered as the less preferred habitat for *Baetis.* Copper (Cu) was positively correlated with the abundance of *B. idei*, *B. lepidus* and *B. minutus* (P<0.05) at a tolerable concentration (mean 0.64±0.4 ppm). It can be concluded that chemical parameters of the rivers do affect the abundance and diversity of *Baetis* species.

Key words: Geographic Information System application, hot spot, mayflies, water quality

INTRODUCTION

Land use changes might affect the ecological systems especially to the abundances of macroinvertebrates who inhabit the rivers including aquatic insects (Meyer & Turner, 1994). Land use activities such as sand-mining, oil palm and maize plantation might disturb the abundance and distribution of benthic macroinvertebrates especially those pollution intolerant groups including order Ephemeroptera. Outmost, the diversity of aquatic insects in tropical river seems higher compared to the temperate region but aquatic insects in temperate region are more abundant in number compared to the tropical region (Hoang & Bae, 2006).

Distribution and abundance of aquatic insects is strongly affected by their tolerance towards an array of environmental factors, including chemical, physical, and biological factors. Aquatic insects vary in sensitivity to organic pollution. Thus, their abundance has been used to make inferences about pollution status of the freshwater as they are classified into very sensitive, sensitive, tolerant and very tolerant groups (McGeoch, 1998; Merritt *et al*., 2008) and one of the important groups of insects used in the bio-assessment of the rivers is Ephemeroptera (mayfly). This is due to their presence in a wide variety of habitats and highly sensitive groups (Nerbonne & Vondracek, 2001). Mayflies or Ephemeroptera are diverse in terms of number of species and they possess numerous functional roles in aquatic environments. Ephemeroptera is an ancient order of fragile insects with many cases of convergent and parallel evolution (Brittain, 1990). Their nymphs are characteristics of shallow streams and littoral areas of lakes and are widely distributed. However, land use activities such as deforestation, agricultural and infrastructure development at the area nearby and recreational activity in the rivers might disturb the characteristics of the river system. In addition,

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ephemeropterans also serve as an important food source for fish and other aquatic vertebrates in the food web (Parkyn *et al*., 2000) and also have been widely used for monitoring the water quality of aquatic environments (Fremling, 1989). Recently, estimating the ecological biodiversity and the way its responds to various kind of pollutions has proven to be an excellent tool in monitoring the aquatic ecosystems (Larsen & Ormerod, 2010).

In Malaysia, ephemeropterans' larvae have been incorporated as freshwater biomonitoring tools in rivers of Gunung Jerai, Kedah (Suhaila *et al*., 2011), Telipok River, Sabah (Kamsia *et al*., 2007), Langat River, Selangor (Azrina *et al*., 2006), Semenyih River, Selangor, (Yap *et al*., 2003), and Kerian River Basin, Perak (Che Salmah *et al*., 2001). Out of all the ephemeropterans, genus *Baetis* is classified as the most sensitive group (Arimoro & Muller, 2010). *Baetis* sp. is the only tolerant and is able to survive within a specified range of water parameters. Besides, changes of water quality parameters in the rivers might alter the abundances and distribution of *Baetis* species as well. Therefore, in this study *Baetis* sp. was selected to provide clearer view on the effects of pollution towards its abundance and distribution. Furthermore, through this study, information about the preferable and hotspot area of *Baetis* sp. and also their distribution in selected rivers at Bukit Merah catchment area in Perak could be obtained.

Therefore, this study was carried out (1) to map the abundances and distributions of *Baetis* species using GIS, (2) to identify the hotspot area of *Baetis* species in relation to chemical parameters at each river and (3) to analyse the chemical parameters that have potential effects on the abundances and distributions of *Baetis* species at several rivers in Bukit Merah catchment area, Perak.

MATERIALS AND METHODS

Description of the study area

This study was carried out at four rivers in Bukit Merah catchment area which are Sungai Ara (N 05º 05' 42.8"/ E 100º 51' 19.3"), Sungai Jelai (N 05º 00' 85.2"/ E 100º 48' 60.4"), Sungai Kurau (N 04º 54' 21.3"/ E 100º 49' 99.1") and Sungai Ayer Itam (N 05º 00' 88.8"/ E 100º 49' 99.8") (Fig. 1). Bukit Merah is located in the Kerian District, at the northern state of Perak. Kerian District is the smallest district in Perak and it borders with three states where Kerian River is the borderline of Penang, Kedah and Perak. In Sungai Ara, there are rubber, oil palm and maize plantations on both sides of the river banks with a buffer zone of about 10 m on each bank. Sungai Jelai passes through villages and receives mainly the sewage from nearby residential areas. One side of the river bank is surrounded with banana plantation. Besides, Sungai Ayer Itam is a recreational river in Bukit Merah, Perak. Local people and villagers were frequently seen for picnic, bathing and even washing motorcycles during the sampling period. In contrast, Sungai Kurau is situated in the virgin forest, Hutan Simpan Bintang Hijau that have less disturbance from human activities.

Distribution mapping and sampling method

Latitude and longitude for each sampling stations were converted to x and y coordinates (Table 1). Ten samples were collected from each river from May 2014 to April 2015. The coordinates for each sampling spots were marked and recorded using Global Positioning Satellite (GPS). The samplings on the next consecutive months were done on the same coordinate. Data collected for this study were

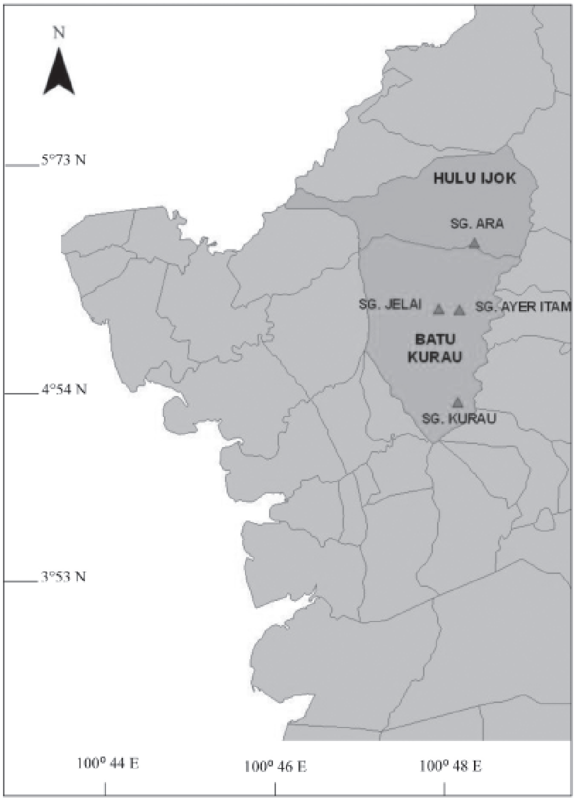

Fig. 1. Location of four sampling stations; Sungai Ara, Jelai, Kurau and Ayer Itam in Bukit Merah catchment area.

Table 1. Location for each sampling station as x and y axis in Bukit Merah catchment area, Perak

	x-axis (East)	y-axis (North)
Sungai Ara	100.853056	5.090722
Sungai Jelai	100.810556	5.013899
Sungai Kurau	100.833333	4.904889
Sungai Ayer Itam	100.835056	5.013222

the abundance of *Baetis* species and water chemical parameters of the river. All the collected data were classified as spatial data. The abundance and distribution of *Baetis* species were collected from the river using kick-sampling technique and further identified in the laboratory using keys from Muller-Liebenau (1984a; 1984b); Dudgeon (1999); Yule and Yong (2004).

Geographical Information System (GIS) was used to input, store, retrieve, manipulate and analyse the collected spatial data. The collected data were mapped using ArcGIS 10.3 Software. Main analysis for this study was to map and analysed the distribution trend of *Baetis* sp. and chemical parameters of the rivers and all the data were analysed using ArcMap and ArcToolbox. All the data layers and shapefiles for the abundances and distribution of *Baetis* sp. and the chemical parameters of the rivers were created for the whole study area. In mapping and analysing the distribution trend of *Baetis* sp. density tools were used. Besides, mapping the chemical parameters of soil was completed using Inverse Distance Weighted (IDW) from interpolation tools. IDW was used in this study since all the sampling stations were in closer points. IDW determined the values by weighted the sample points and the obtained values indicates the influenced of sample points.

Measurements of water quality parameters

Water temperature (°C), dissolved oxygen (DO), total suspended solid (TSS), pH value and ammonia-nitrogen (NH_3-N) were determined *in situ* using YSI Model 550A (YSI Inc., Ohio, USA). All these parameters were measured and recorded at three randomly selected locations at each river. Water samples were collected concurrently with the aquatic insects sampling, a 500 ml polyethylene bottles was used to collect water sample from each river. The polyethylene bottle was rinsed with river water before the actual water sample was taken. A black bottle was used to avoid sunlight exposure to measure biochemical oxygen demand (BOD). DO reading on the first day was measured using YSI Pro-BOD Probe and Pro20 instruments. Then, the water sample was incubated in a dark place at temperature 20°C. After 5 days of incubation, another reading of dissolved oxygen was taken. The differences in dissolved oxygen levels between first and fifth day after incubation is the amount of BOD_5 of the water. The BOD_5 is expressed in milligrams per liter of DO using the following equation:

BOD_5 = DO_1 reading on the first day – DO_5 reading on the third day

Sample preparation for the COD analysis was completed using HACH DRB 200 COD Reactor. The total suspended solid (TSS), and COD of the water sample were measured in the laboratory using a standard kit of DR/890 HACH Calorimeter (HACH CO., Loveland, USA). The mean values of the six parameters (DO, BOD_5, COD, pH, AN and TSS) were used for the calculation of Water Quality Index (WQI). According to Department of Environment (DOE, 2001), WQI was calculated using the following equation:

$$WQI = 0.22*SIDO + 0.19*SIBOD + 0.16*SICOD + 0.15*SIAN + 0.16*SISS + 0.12*SIpH$$

Measurements of total organic contents and heavy metals in soil samples

Sediment samples were collected on every sampling occasion at each river and air-dried in the laboratory for analysis of total organic and heavy metal content; [Ferum (Fe), Nickel (Ni), Chromium (Cr), Copper (Cu) and Lead (Pb)]. Approximately, 100 g river bottom sediment were sampled, placed in plastic bags and transported in a Coleman ice chest to the laboratory. The dried sediment was grounded and sieved. The total organic content analysis was performed following ASTM-D2974-87 (1987). In the laboratory, the mass of an empty, clean and dry porcelain dish was determined and recorded (MP). Ten g of soil sample was placed into the porcelain dish. After that, the mass of the porcelain dish and soil were determined and recorded (MPDS). Then, the dish was placed in a muffle furnace at 440°C and was left overnight. After that, the porcelain dish was removed carefully from the furnace. The porcelain dish together with the sample was left to cool to room temperature in a desiccator. The mass of the dish containing the ash (burned soil), MPA was determined and recorded. Percentage of organic matter in the soil was calculated following standardised calculation by ASTM-D2974-87, (1987) as shown below:

Mass of the dry soil, MD = MPDS – MP
Mass of the ash (burned soil), MA = MPA – MP
Mass of organic matter, MO = MD – MA
Organic content, OM = (MO/MD) x 100

The heavy metal analysis was performed following modified method from Abbruzzini *et al.* (2014). Digestion was performed using Microwave Accelerated Reaction System (MARS) (CEM Corporation). Samples were weighted to 0.5 g and then 15 ml of HNO_3 (trace metal grade) was added to each digestion vessels. The samples were left for pre-digestion reaction about 10 minutes. Then, the vessels were placed in the microwave and heated to 200°C with 800 PSI. After appropriate RAMP time (RAMP to temperature: 15 minutes), the vessels were taken out from the microwave. The mixture was filtered through 0.45 um filter paper to separate the non-residual solution (Abbruzzini *et al*., 2014). The final solution of the samples were tested for heavy metal content using 700 Series ICP-OES (Agilent Technologies) with appropriate wavelength settings for specific metal.

Data analysis

Normality test, Kolmogorov-Smirnov was conducted to examine the distribution of the data and thus the data were not normally distributed at $P<0.05$. Kruskal-Wallis test was conducted on the abundance of *Baetis* species among the four sampling sites. Spearman rho's correlation was tested between chemical parameters of water and soil sediments with the abundances of *Baetis* sp. to analyse the relationship between them. All statistical analysis was conducted using IBM Statistical Package for Social Science (SPSS) version 20.

RESULTS

Abundance and distribution trend of *Baetis* species in selected sampling stations of Bukit Merah catchment area

Throughout 12 months of study period, 530 individuals of *Baetis* species from seven *Baetis* species (*B. gombaki*, *B. idei*, *B. illiesi*, *B. laetificus*, *B. lepidus*, *B. minutus* and *B. mirabilis*) were collected from Sungai Ara, Jelai, Kurau and Ayer Itam (Table 2). *B. illiesi* was the dominant species (22.6%) from the four sampling stations with 120 individuals followed by *B. idei* (22.5%) with 119 individuals and *B. laetificus* (17.5%) with 93 individuals collected. From the four sampling stations, *B. lepidus* had the lowest individuals collected with only 16 individuals and contributed only 3% from the total *Baetis* species collected. The Kruskal-Wallis test showed that there were significant differences of the abundances of seven *Baetis* sp. ($\chi^2=58.75$, $P=0.00$) and among the four sampling stations ($\chi^2=46.25$, $P=0.00$).

Sungai Ara had the highest abundances of *Baetis* sp. collected (255 individuals). In contrast, Sungai Ayer Itam had the lowest abundances of *Baetis* sp. with only 79 individuals collected. The dominant species in Sungai Ara was *B. illiesi* (65 individuals), followed by *B. minutus* (49 individuals) and *B. idei* (48 individuals). *B. illiesi* and *B. laetificus* were the dominant species in Sungai Kurau and Ayer Itam while *B. idei* was the dominant species collected in Sungai Jelai. However, *B. lepidus* had the lowest abundances in all four rivers.

Hotspot area of all *Baetis* species among the selected sampling stations in Bukit Merah catchment area

The preferable and hotspot area for each *Baetis* sp. could be clearly seen through the output map produced via GIS analysis. In this present study, Sungai Ara had the greatest density and abundances of all the *Baetis* sp. compared to the other sampling stations. Therefore, Sungai Ara was classified as the hotspot area for the abundances and distributions of *Baetis* sp. (Fig. 2). Besides, Sungai Kurau was considered as the less preferred habitat for *Baetis* sp. because it had the least abundances of *Baetis* sp. The greatest density of all *Baetis* sp.; *B. gombaki*, *B. idei, B. illiesi, B. laetificus, B. lepidus, B. minutus* and *B. mirabilis* was from Sungai Ara (Table 3).

Concentration of heavy metal of four sampling stations in Bukit Merah catchment area

Out of all the heavy metals collected in the sediment of Sungai Ara, Cu had the highest concentration with 0.64 ppm followed by Pb (0.38 ppm) and Fe (0.32 ppm) respectively (Table 4). In addition, the highest concentration of heavy metal detected in Sungai Kurau was Fe with 4.96 ppm while Pb was not detected in Sungai Kurau. Besides,

Table 2. Composition of *Baetis* sp. collected from all sampling stations (May 2014 – April 2015)

Species	No. of individuals				Total	%
	Ara	Jelai	Kurau	Ayer Itam		
Baetis gombaki	21	119	11	5	50	9.4
Baetis idei	48	120	11	10	119	22.5
Baetis illiesi	65	93	21	23	120	22.7
Baetis laetificus	42	16	21	23	93	17.5
Baetis lepidus	10	77	2	0	16	3.0
Baetis minutus	49	55	6	10	77	14.5
Baetis mirabilis	20	12	15	8	55	10.4
Total	255	109	87	79	530	100

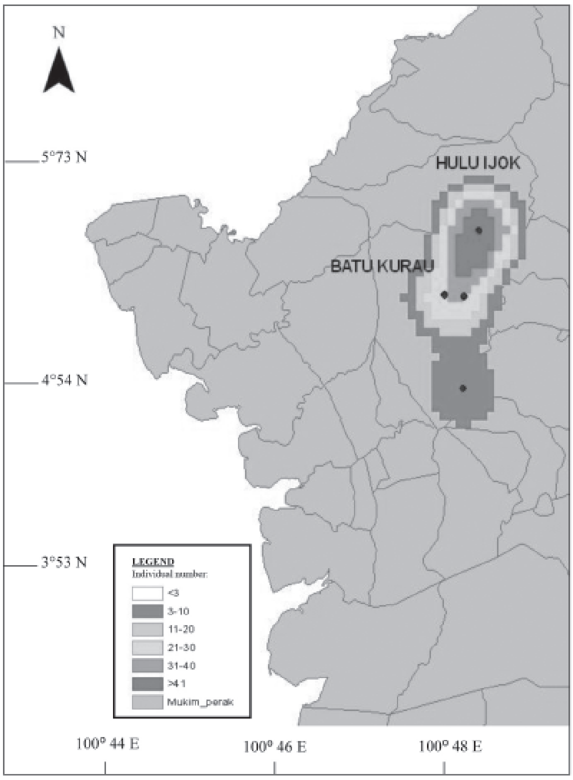

Fig. 2. Hotspot area for the abundances and distribution of *Baetis* sp. in four sampling stations (Highest attribute value = Sungai Ara: 44).

Table 3. Attribute values on the density of *Baetis* species in Sungai Ara

Species	Density
Baetis gombaki	6
Baetis idei	8
Baetis illiesi	18
Baetis laetificus	8
Baetis lepidus	3
Baetis minutus	8
Baetis mirabilis	9

out of all metals studied in Sungai Ayer Itam, Fe had the highest concentration with 10.51 ppm which was the highest among the four rivers. Cu was not detected in Sungai Ayer Itam. In contrast, all the heavy metals were present and detected in Sungai Jelai. The highest concentration of heavy metals in Sungai Jelai was Fe (2.76 ppm) followed by Cr (1.20 ppm), Pb (0.32 ppm), Ni (0.08 ppm) and Cu (0.01 ppm). In addition, organic content detected from the sediments were recorded highest in Sungai Jelai with 1.56% followed by Sungai Kurau (1.52%), Ara (1.49%) and Ayer Itam (1.38%).

Overall, six *Baetis* sp. were slightly influenced by two or more chemical parameters of the rivers (Table 5). However, *B. mirabilis* did not have any correlations with any parameters. Con-comitantly, DO, BOD, water temperature and velocity showed impacts on the abundance and distribution of *Baetis* sp. since $P<0.05$. Out of all the water chemical parameters, *B. idei* showed correlation with water temperature (r=0.723, P=0.00) and BOD (r=0.719, P=0.00). The abundance of *B. gombaki* only correlated with water temperature (r=0.499, P=0.001). Based on Water Quality Index (WQI), all studied rivers fall into class II. Sungai Ara had the greatest WQI value (84.36) indicating that this river had a better water quality compared to others.

Four *Baetis* sp. (*B. idei*, *B. laetificus*, *B. lepidus* and *B. minutus*) were slightly influenced by two or more chemical parameters of soil sediments (Table 6). *B. idei, B. laetificus*, *B. minutus* and *B. lepidus* were more sensitive towards changes in chemical parameters of soil sediments since they correlated with more variables. Similar to chemical parameter of water samples, *B. mirabilis* did not correlate with any chemical parameters of soil sediments. The content of Ferum (Fe) in the soil sediments had the highest influence on the distribution of *B. idei* with r=-0.723, P=0.000. Besides, through IDW analysis, the highest concentration of heavy metals in the soil sediments was from Sungai Ayer Itam whereas the

Table 4. Heavy metal contents (mean ± SE) in the sediments from all the four rivers in Bukit Merah, Perak. All concentrations are shown in part per million (ppm) except for organic content

Heavy metal	Sungai Ara	Sungai Jelai	Sungai Kurau	Sungai Ayer Itam
Chromium (Cr)	ND	1.20 ± 0.54	0.45 ± 0.04	0.13 ± 0.08
Copper (Cu)	0.64 ± 0.38	0.01 ± 0.02	0.37 ± 0.19	ND
Ferum (Fe)	0.32 ± 0.00	2.76 ± 1.68	4.96 ± 2.19	10.51 ± 4.01
Nickel (Ni)	ND	0.08 ± 0.13	2.73 ± 0.95	0.45 ± 0.29
Lead (Pb)	0.38 ± 0.13	0.32 ± 0.12	ND	0.11 ± 0.02
Organic content (%)	1.49 ± 0.13	1.56 ± 0.11	1.52 ± 0.29	1.38 ± 0.17

ND: not detected (below detection limit of the ICP-OES)

Table 5. River classification based on Water Quality Index (WQI) for Sungai Ara, Jelai, Kurau and Ayer Itam in Bukit Merah, Perak

Parameters	Sungai			
	Ara	Jelai	Kurau	Ayer Itam
Water temperature (ºC)	26.33 ± 0.38	25.45 ± 0.32	24.59 ± 0.38	24.45 ± 0.32
DO (%)	96.1±3.36	87.38±2.77	94.5±2.61	94.06±2.62
BOD (mg/L)	1.07±0.21	0.95±0.24	0.50±0.10	0.71±0.09
COD (mg/L)	15.92±6.31	35.58±14.91	30.0±13.41	47.56±14.7
AN (mg/L)	1.99±0.64	2.11±0.64	1.70±0.5	2.21±0.67
TSS (mg/L)	3.58±0.92	8.17±2.64	2.92±0.93	3.88±1.09
pH	6.88±0.19	7.28±0.17	6.97±0.18	7.14±0.13
WQI value	84.36	79.2	83.14	78.92
Class	II	II	II	II

Table 6. Attribute values of heavy metal contents in the soil sediments from four sampling stations in Bukit Merah catchment area

Sampling stations (River)	x-axis	y-axis	Attribute values of heavy metal contents
Ara	100.853056	5.090722	3.14
Jelai	100.810556	5.013899	5.93
Kurau	100.833333	4.904889	10.29
Ayer Itam	100.835056	5.013222	12.74

lowest concentration was reported in Sungai Ara (Table 6). The distribution of heavy metal contents in the four sampling stations could be clearly seen through the output map produced (Fig. 3). Meanwhile, total organic contents in the soil sediments did not correlate with the abundance and distribution of any *Baetis* sp. (P>0.05). The IDW analysis recorded highest concentration of total organic contents in the soil sediments from Sungai Kurau while the lowest concentration was reported from Sungai Ayer Itam (Table 7). The distribution of heavy metal contents in the four sampling stations could be clearly seen through the output map produced (Fig. 4).

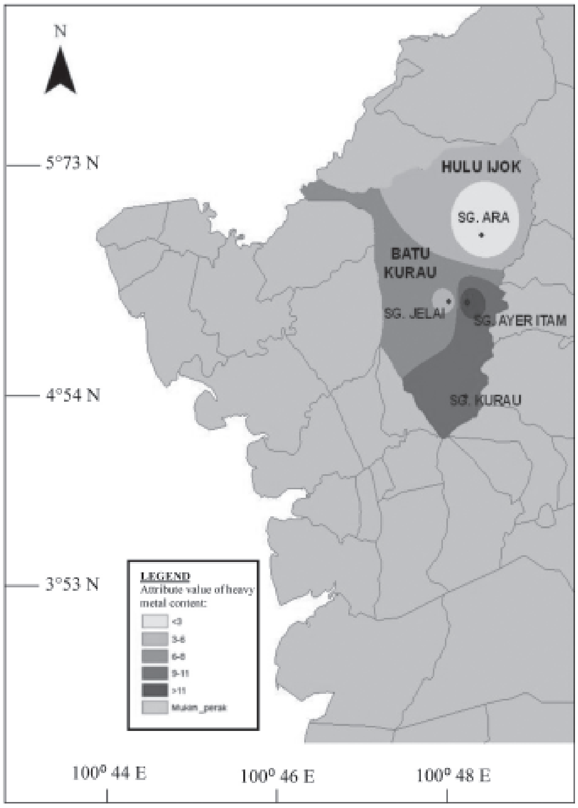

Fig. 3. Heavy metal contents in four sampling stations in Bukit Merah catchment area.

DISCUSSION

In this present study, the greatest abundances of *Baetis* species was collected from Sungai Ara followed by Sungai Jelai, Kurau and Ayer Itam and was confirmed by the attribute values. Large number of *Baetis* sp. was collected from Sungai Ara suggesting that this ephemeropterans are tolerant to the environmental differences (Suhaila *et al.,* 2011). Different types of human activities at the nearby area might cause changes in abundances and

Table 7. Attribute values of total organic contents in the soil sediments from four sampling stations in Bukit Merah catchment area

Sampling stations (River)	x-axis	y-axis	Attribute values of total organic contents
Ara	100.853056	5.090722	1.493
Jelai	100.810556	5.013899	1.556
Kurau	100.833333	4.904889	1.65
Ayer Itam	100.835056	5.013222	1.38

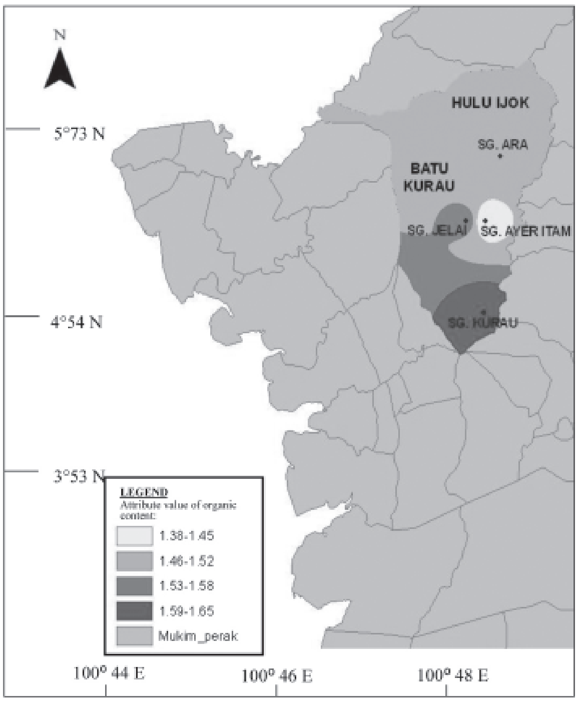

Fig. 4. Total organic content (%) in four sampling stations in Bukit Merah.

composition of *Baetis* species (Arimoro *et al.,* 2011; Arimoro & Ikomi, 2008). Matthaei *et al*. (2000) also stated that the abundance and distribution of *Baetis* sp. in the rivers are strongly influenced by anthropogenic impact which causes changes in conductivity, nutrients and dissolved oxygen levels. Similarly, Margolis *et al.* (2001) also claimed that changes in *Baetis* sp. assemblages are not determined by changes in the type and availability of food, but it depends on the resident species to tolerate with its surrounding environment. Meanwhile, previous study done by Rutt *et al.* (1989), Jenkins *et al*. (1984) and Dudgeon (1982) showed that overlap of habitat is frequent between *Baetis* sp. Jenkins *et al*. (1984) found that some of the *Baetis* sp. are abundant in root of marginal vegetation but the two other *Baetis* (*B. niger* and *B. rhodani*) are abundant among riffles, stony substrate and aquatic macrophytes.

The highest abundance of *Baetis* in Sungai Ara was due to the presence of suitable conditions for the survival of *Baetis* larvae such as the presence of aquatic plants and suitable substrate's type such as gravel and sand. In this present study, it could be seen that *Baetis* preferred habitat with dominant substrate types of cobble, gravel and sand. This is similar to previous study by Bunn *et al*. (1999) where the similar composition of substrate type with Sungai Ara and Jelai resulted in greater abundance of *Baetis* sp. In this present study, Sungai Ara and Jelai had higher abundances of *Baetis* compared to Sungai Kurau and Ayer Itam. In contrast, stony substrate in Sungai Ara and Jelai were almost clean and free from moss while in Sungai Kurau and Ayer Itam, most of them were covered with moss. Besides, Sungai Ayer Itam had the lowest abundance of *Baetis* sp. which could be the result of human interference which was unsuitable for *Baetis* survival (Duan *et al*., 2009).

Other than that, various chemical parameters of the river's water also contributed major effects on the abundance and distribution of *Baetis* species. Chemical parameters of the rivers are used to set the water quality standard and also to classify the river class based on their range of water quality (DOE, 2001). High abundances of *Baetis* sp. in certain river often signify good quality of water parameters (Mason, 1996). The results from the present study indicates that the abundance, distribution and composition of *Baetis* sp. in each river appeared to respond to the water quality parameters. Some *Baetis* sp. showed selective distribution, being found in distinct numbers at specific river. In this study, it was found that *B. idei* preferred a habitat with cooler water temperature and high BOD concentration while *B. mirabilis* is tolerant to all parameters in all studied rivers. This might be due to the low value of physicochemical parameters at each river.

The dominant chemical parameter that affected the abundances and distribution of *Baetis* sp. in this study was water temperature. The abundances of *B. gombaki*, *B. idei*, *B. lepidus* and *B. minutus* would increase if water temperature increases. Findings from this study showed that the four *Baetis* species; *B. gombaki*, *B. idei*, *B. lepidus* and *B. minutus* were tolerant to the changes in water temperature (24ºC to 27ºC) and only survive in great concentration of dissolved oxygen (85% to 98%) (DOE, 2002). According to Wan Mohd Hafezul *et al.* (2016), water temperature is a strong descriptor of changes in abundance of Ephemeroptera. For aquatic invertebrates, small changes in water temperature (2–5ºC) would result in apparent changes in their composition (Sweeney, 1995). In addition, increase in water temperature would decrease the solubility of oxygen in the water (DOE, 2002). The abundance of *B. gombaki*, *B. idei*, *B. lepidus* and *B. minutus* did not be affected even if the water temperature increased as long as it is still within the tolerable limits.

Besides, *B. idei*, *B. lepidus* and *B. minutus* were positively correlated with water velocity, meaning the abundances of those three species will increase concurrently with faster water flow. Faster water flow may provide more oxygen to be dissolve in the water due to water turbulence. In addition, there are greater abundance of *Baetis* sp. larvae in river bed that embedded with cobbles due to higher dissolved oxygen concentration in this type of microhabitat. Another important factor affecting the abundances and distribution of *Baetis* sp. is the concentration of dissolved oxygen (Ward, 1992). *B. illiesi*, *B. laetificus* and *B. minutus* were positively correlated with the concentration of dissolved oxygen in the river similar to finding from Suhaila *et al.* (2011) that reported *Baetis* was strongly associated with DO levels in rivers running down from Gunung Jerai, Kedah.

From the IDW analysis, it can be seen that Sungai Kurau had the highest amount of organic contents in the soil sediment compared to Sungai Ara, Jelai and Ayer Itam. Sungai Kurau is located in the forest area. The large amount of organic content might be due to the decomposition of leaves and wood from the forest (Tabacchi *et al*., 1998). Besides, Sungai Kurau was the least preferable hotspot area among the other sampling stations. From these findings, it can be seen that *Baetis* species preferred to inhabit in the area with low organic content. In this present study, Sungai Ara was the most preferred habitat of *Baetis* species compared to other rivers because Sungai Ara had the lowest amount of organic content. Similarly, previous study done by Sporka *et al*. (2006) also showed that *Baetis* sp. preferred habitat with low amount of organic content.

In addition, from the Spearmans' rho correlation, it could be seen that Copper (Cu) was positively correlated with the abundance of *B. idei*, *B. lepidus* and *B. minutus*. The tolerable limits of Cu concentration differ among *Baetis* species and also between the habitats. Fialkowski *et al*. (2003) showed *B. rhodani* and *B. vernus* were indicator for Cu contamination in Upper Silesia, Poland. *Baetis* species that were exposed to heavy metals content in the rivers' sediment might be able to tolerate with those pollutants (Cain *et al*., 1992). Furthermore, other heavy metals such as Chromium (Cr), Ferum (Fe) and Nickel (Ni) in the soil sediments were negatively correlated with all the *Baetis* species except for *B. mirabilis*. This indicates that the abundances of all the six *Baetis* species would be affected when the concentration of Cr, Fe and Ni increased.

CONCLUSION

The hotspot and least preferable habitat of *Baetis* sp. could be clearly seen through IDW analysis. Sungai Ara was the most preferable hotspot area for many *Baetis* species due to greater diversity of *Baetis* sp. in Sungai Ara while Sungai Kurau was the least preferable habitat for *Baetis* species. Variation of chemical parameters of the rivers had major influenced on the abundance and distribution of *Baetis* species. In this present study, water velocity, temperature and DO in water sample while Cr and Fe in the soil sediments were the dominant parameters affecting the abundance and distribution of *Baetis* sp. at each sampling stations. Out of the seven *Baetis* sp., *B. laetificus* was the most sensitive *Baetis* species, followed by *B. minutus*. *B. laetificus* and *B. minutus* correlated with most of the studied chemical parameters. In contrast, *B. gombaki* was the least sensitive *Baetis* species as it only correlated with water temperature. It can be concluded that heavy metal content in the rivers from Bukit Merah catchment area are very low and *Baetis* species collected in this area are the flag species that need to be monitored in the future as they are an important bio-indicators for water quality and water pollution detection.

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